A Case Based Human Reliability Assessment Using HFACS For Complex Space Operations

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Abstract

Multiple studies have shown that more than half of aviation, aerospace and aeronautics incidents are attributed to human error.   Although many existing incident report systems have been beneficial for identifying engineering failures, most of them are not designed around a theoretical framework of human error, thus failing to address core issues and causes of the mishaps. In addition, the collection and classification of human error data can be a challenge, including the causal factors that impact human behavior. Therefore, it is imperative to develop a human error assessment framework to identify these causes [1]. The objective of this article is to provide a high-level literature overview and comparison of relevant human error assessment methods and provide an example of how one of these tools can be used to perform a human error analysis for complex space operations.   The Human Factors Analysis and Classification System (HFACS) is one tool that can be used to categorize human error causal factors in a Space Operations environment.   Due to the uniqueness of Space Operations and its complexity, there are very limited Human Reliability Assessment (HRA) tools specifically established for identifying and assessing human error. It is recommended that further research be done to fill the gap of HRAs, as it applies specifically to Ground Processing Operations.

1.0 Introduction

Several published studies show various types of Human Reliability Assessment (HRA) tools that are used for human error analysis and human error probability. However, most of these tools were created from the aeronautics, aviation, mining, nuclear power or chemical process industry perspective. Due to the uniqueness of Space Operations and its complexity, it is imperative that Human Reliability Assessment tools are established as specific resources for identifying and assessing human error in a Space Exploration environment. Research reveals that 70-80% of all aviation incidents involve human factors [19]. In the field of Human Factors, there are several Human Reliability Assessment tools for measuring human error and its probability; however, amongst the various types, there are none specifically designed for complex space operations, such as National Aeronautics and Space Administration (NASA) Ground Processing Operations. The purpose of this article is to provide a high-level overview and comparison of relevant human error assessment methods and tools for human error analysis and error prediction, with the objective of highlighting one of the tools and providing an example of how this tool can be used to perform a human error analysis for complex space operations. These methods and their comparisons can be found in Appendix A. Out of the 15 HRAs listed in this article, the Human Factors Analysis and Classification System (HFACS) will be highlighted and a case study provided to demonstrate its applicability to human error analysis in Space Operations. The

HFACS was selected for this article due to its broad analysis of human error that considers multiple causes of human failure [21]. One of the benefits to using HFACS is that the generic terms and descriptors allow it to be used for a range of industries and activities [14,1].

In this article, NASA KSC Ground Processing Operations was used as the main reference data, due to the fact that it is a major vehicle spaceport.

1.1 Human Factors Analysis and Classification System (HFACS)

The Human Factors Analysis and Classification System (HFACS) is largely based on James Reason's Generic Error Modeling systems (GEMS) conceptual framework, with the framework's intent to identify the origin of basic human error types [13, 1]. The HFACS lists human errors at each of the four levels of failure: 1) Unsafe Acts of Operators, 2) Preconditions for Unsafe Acts, 3) Unsafe Supervision, and 4) Organizational Influences (which can be multiple causes) [21]. Nineteen (19) causal categories within the four categories of level of failures are also established for human failure [1].

Developed by Dr. Scott Shappell and Dr. Doug Wiegmann, HFACS serves as a response to data from the Navy and Marine Corp that recognized human error as the leading primary cause for approximately 80% of all of their flight accidents. HFACS is used to categorize human causes of accidents and serves as a means to assist in the investigation of those causes. It also helps identify human causes of accidents, with the objective of establishing training and prevention efforts [21,1].

2.0 Methodology

The case study presented in this article exhibits how the HFACS system can be used to categorize existing human factors in a complex ground processing operation. The incident was selected and used because of the SpaceShipTwo (SS2) rocket powered test flight, similar aspects

of space flight and its systems complexity.   For illustration purposes, this article will not focus on the accident causal factors. This will be left to the National Transportation Safety Board (NTSB) report to identify the accident causal factors.

According to Chandler [3], "Ground processing (as it relates to Space Mission Human activity) includes a wide variety of human activities, such as system design, manufacturing and systems acquisition, vehicle assembly, preparation of science payloads, payload assembly, integrated vehicle and payload processing and test, vehicle maintenance and repair, transport of the vehicle, and crew launch day preparation" (p. 154).

The incident used in this case study had an official investigation report performed by the National Transportation Safety Board (NTSB). For this article, the final report was used as a primary source of information for the SpaceShipTwo rocket test flight mishap.

Because the NTSB investigation is one report concerning the SpaceShipTwo rocket test flight mishap, there may be additional reports generated on this same topic. Some readers of this article may have additional information to what is represented, some readers may disagree on the analysis, methodology, approach, etc. The goal of this case study is to not reinvestigate or recreate the accident. The case study will be performed solely on the information made readily available and within the bounds of the NTSB report.

2.1 Case Study analysis using HFACS

In Flight Breakup During Test Flight Scaled Composites SpaceShipTwo: *"On October 31, 2014, at 1007:32 Pacific daylight time, the SpaceShipTwo (SS2) reusable suborbital rocket, N339SS, operated by Scaled Composites LLC (Scaled), broke up into multiple pieces during a rocket-powered test flight and impacted terrain over a 5-mile area near Koehn Dry Lake,*

California. The pilot received serious injuries, and the copilot received fatal injuries. SS2 was

destroyed, and no one on the ground was injured as a result of the falling debris. [11]"

When conducting a HFACS analysis, there are many ways this can be performed. In the structured format of the NTSB investigation and analysis report used in this article, the executive summary served as a starting point for presenting the information and conducting the analysis, then it was worked backwards in time from that point. For the case analysis, this article will follow the same process.

When using HFACS as a classifying tool, the categorization process can be a two or three step process, which is dependent upon the Classification level you are working with [22]. The levels are: Unsafe Acts (Level 1), Preconditions of Unsafe Acts (Level 2), Unsafe Supervision (Level 3) and Organizational Influence (Level 4) (Fig. 1). Figure 1 shows the four levels, with sublevels. There are some specific casual factor examples for the lower sublevels, but they are not included in the figure 1, but can be found in HFACS reference material [21,22].
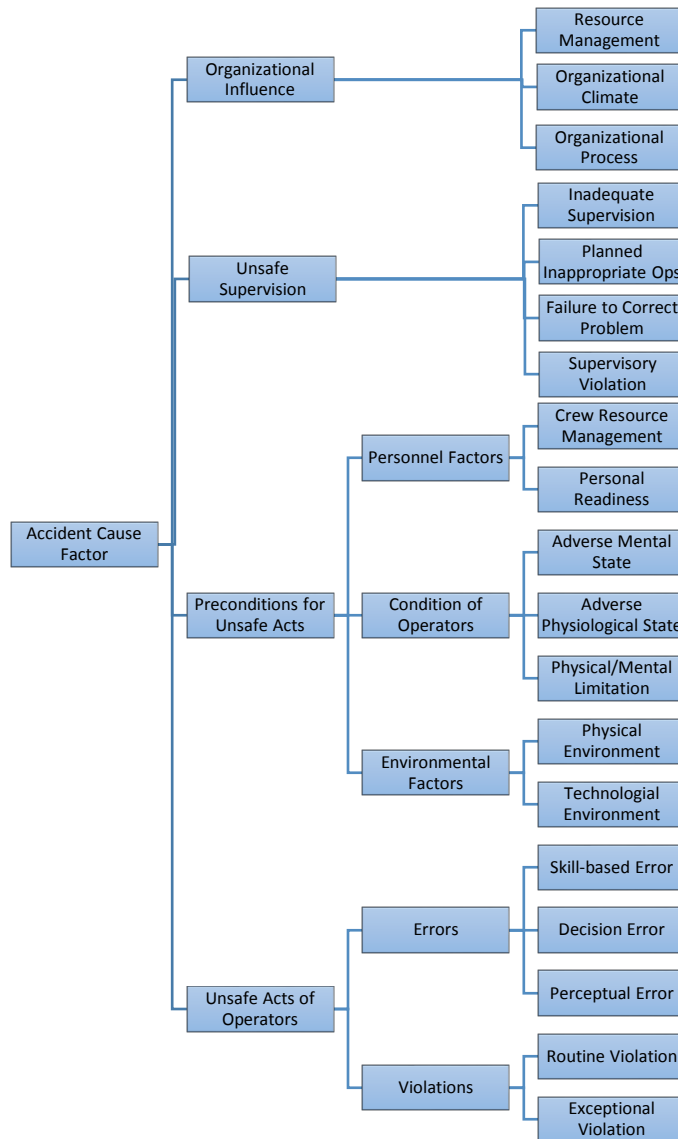
Figure 1: Steps required to classify causal factors using Human Factors Analysis and Classification System (HFACS) [22]

Prior to the SS2 accident, it was the SS2 co-pilot's decision to unlock the feather just after the SpaceShipTwo rocket reached 0.8 Mach speed. Per the fight test, the data used during the flight test specified that the feather was to be unlocked during the boost phase when the SS2 reached 1.4 Mach [11]. This requirement was to serve as a mitigation to the potential hazard of the SS2 vehicle's reentry with the feather down, as a result of a lock failure [11].

The co-pilot's decision to unlock the feather at the wrong Mach speed, was an unsafe act, which places this action under the Level 1, *unsafe acts of operations* category. Under this category there are two sublevel categories: "error" and "violation." The next step is to determine what type of error and/or violation it was. Based on the action of the co-pilot, this was an error of the co-pilot, established on a decision he made, so this would fall under the *decision error* Level 1 subcategory. In a post interview with the surviving pilot, the NTSB report documents, "The pilot stated that he was unaware during the flight that the copilot had unlocked the feather early. The pilot also stated that he and the copilot were briefed "multiple" times that the copilot was to unlock the feather at 1.4 Mach [11]." Knowing that the pilot and co-pilot were briefed the correct process multiple times for unlocking the feather, the co-pilot's action was also a **v***iolation.*

Per James Reason, an *exceptional violation*, is one that is considered an isolated departure from authority, not necessarily indicative of an individual's typical behaving pattern [12]. This violation is also commonly referred to as "bending the rules." Due to the fact that this was a first of a future flight test, and was not a routinely performed operation, this action would fall under the *exceptional violation* category.

While continuing with the analysis, per the NTSB report, as a part of the rocket powered flight test, an experimental permit was required in order to perform the test. This required Scaled Composites to complete and submit an experimental permit application to the Federal Aviation Administration's (FAA) Office of Commercial Space Transportation's (AST), (FAA/AST) for review and approval [11]. As a part of the process regulation there is a hazard analysis requirement per 14 CFR 437.55, which required Scaled Composites to "identify and describe those hazards that could result from human errors." In Scaled Composites' SS2 hazard analysis, they did not identify and document the likelihood that "a pilot could prematurely unlock the feather systems, which

would permit the feather to extend under conditions that could lead to a catastrophic failure of the vehicle's structure [11]." Rather, Scaled Composites presumed the pilots would have received appropriate training by means of simulation sessions, therefore equipping them to know how to accurately operate the feather system, per the standard and emergency procedures for a specified situation [11]. Despite the fact that the flight crewmember had extensive flight test experience and completed many preflight simulations, in which the feather was unlocked at the appropriate 1.4 Mach speed, this accident is testament that errors can still occur [20].

Due to Scaled Composites' failure to identify and document the likelihood of a premature feather unlocking as a potential hazard and its appropriate control or mitigation for this, this falls under the Level 3 *unsafe supervision* category. This lack of identification reduced the effectiveness of any type of mitigation, because this possibility was not identified as a hazard. More specifically, because Scaled Composites' leadership failed to identify and provide mitigation to correct a known (possible) problem, this would fall under the *failure to correct a known problem* subcategory.

For demonstration purposes, the NTSB report does not state if the simulation training sufficiently trained the crewmembers; however, if this was the case (e.g. insufficient training), then this would also fall under the Level 3 *unsafe supervision,* subcategory *inadequate supervision* with causal example *failed to provide proper training.* In this analysis, some questions to consider would be "Did the simulation training environment provided fail the crew members?" "Was it adequate for them?" If this was the case (training environment failure and inadequacy), then this would fall under the *preconditions of unsafe acts* Level 2, under the *environmental factors*, and *technological environment* subcategories. However, as stated before, this is not known from the report.

The FAA/AST granted Scaled Composites its initial experimental permit, first and second renewals of the permit. Following the first renewal, the FAA/AST performed an additional review of SS2's hazard analysis, which was a part of Scaled Composites' application, and made the decision that the hazard analysis failed short of the 14 CFR 437.55(a)'s software and human error requirements [11]. Consequently, for the first renewal of the experimental permit, the FAA/AST provided a waiver from these hazard analysis requirements. The waiver was not requested by Scaled Composites, nor were they involved in the assessment process, nor did they provide feedback concerning the waiver, prior to its administration. The FAA/AST also provided additional waivers from these hazard analysis requirements as part of the second renewal. It was determined by the FAA/AST that the waivers were in the public interest and would not increase risk to public health. The FAA/AST also decided that despite the fact the Scaled Composites hazard analysis was not compliant to the software and human error requirements, that particular mitigations that were put in place by Scaled Composites would inhibit such error results. Nonetheless, the waivers provided by the FAA/AST lacked the proper awareness of whether the mitigations would sufficiently safeguard from "a single human error with catastrophic consequents [11]." Also, none of the mitigations were determined to adequately ensure public safety [11].

When performing a HFACS analysis, some causal factors may not be identified within the HFACS framework, because they are not typically within an organization's sphere of influence [22]. These factors are rather considered *outside influences* that have the likelihood of contributing to an accident [22]. The FAA/AST's decision to determine that the waivers were in the public's best interest and would not increase health, safety, property, and national security risks, along with the fact that FAA/AST's waiver lacked coordination and proper awareness with SS2, would be considered an *outside influence.*

Lastly, based on the incident report, Scaled Composites overlooked an opportunity to recognize design and/or operations requirements, due to their lack of human factors application and consideration as a "potential cause of uncommand feather extension on the SS2[11]."

As a result of Scaled Composites' lack of human factors consideration in the design, operation procedures, hazard analysis and flight crew simulation training, this causal factor would be classified as a *failure to correct known design flaws*, which falls under the *resource management* category under the 4th Level *organizational influences.*

3.0 Results

As it relates to flight accidents, generally most accidents could have been impeded at several levels (Fig. 2). Due to Scaled Composites' lack of human factors consideration in several levels and aspects of the experimental flight, this contributed to and established the grounds for a potential accident. However, there were several other causal factors that contributed to the incident, such as the co-pilot's decision to unlock the feather at the wrong Mach speed, and the FAA/AST's decision to approve waivers without coordination and proper awareness with SS2. Figure 2 illustrates how failed defenses in Reason's Swiss cheese model [13] led to an accident.
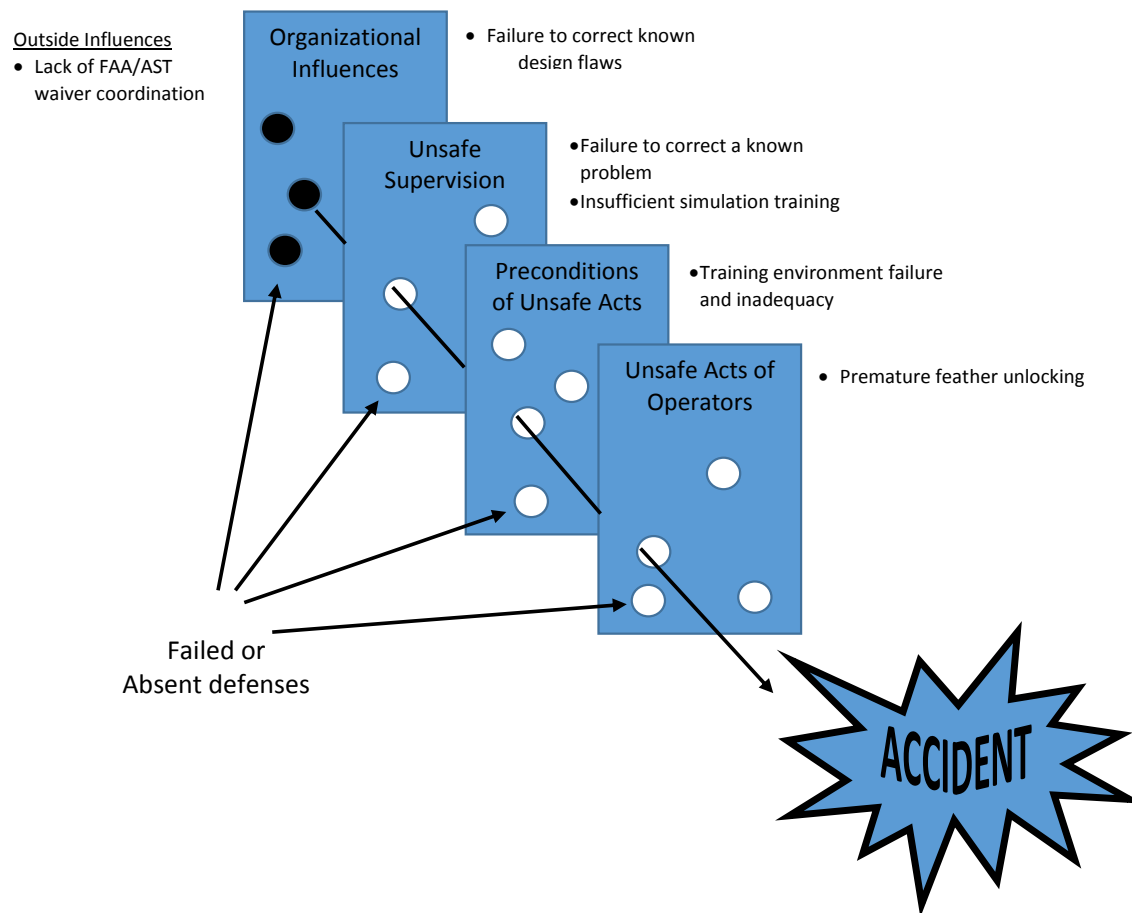
Figure 2: Summary of Scaled Composites' SpaceShipTwo In Flight Breakup during Test Flight [11, 22]

4.0 Discussion

Amongst the HRA methodologies discussed in Appendix A, none of them were developed specifically for aerospace and spaceflight applications. They were created from a myriad of tools developed from an aeronautics, aviation, mining, nuclear power or chemical process industry perspective.

The review in Appendix A reveals that the topic of adequate current HRAs for complex systems, should continue to be discussed. It is recommended that existing validated HRAs that have been used to successfully perform analyses on similar complex operations, such as the ones listed in Appendix A of this article, but not limited to, be modified to address unique complex systems in a Space Operations environment.

Discussion for a modified version of an existing validated HRA methodology and framework should be considered for the development of future complex space operations, such as Ground Processing Operations (GPO). Some examples of potential human error causal factors in Ground processing operations are: poor access, excessive task loading, failure to stop work due to a safety/hazard concern, failure to complete procedure steps, confined space, etc. [1].

This article focused on one the HRAs considered in the HRAs selected by the NASA 2006 study (i.e. HFACS); however, this does not encompass all of the existing HRAs available for consideration (e.g., social-technical approaches, etc.). The NASA 2006 study team selected four HRAs (THERP, CREAM, NARA and SPAR-H), stating that these methods individually did not meet all of NASA's selection criteria [3]. Therefore, the concept of modifying existing HRAs for complex space operations, should be considered. These modified HRAs, frameworks and methodologies are not limited to one HRA, but could consist of a hybrid of two or more HRAs.

Considerations for a modified existing HRA are below:

1) Modify an existing HRA by identifying aspects of the specific complex operation that can be matched to the task, performance shaping factors, levels of failures, etc.

2) Identify other HRAs equivalent in nature and the risks that can be modified to fit the criteria or needs of a specific complete operation, such as ground processing operations.

3) Review the existing complex space operation's historical data to build a framework and modify an existing HRA.

4) Validate the developed framework and modified HRA for use.

Using HFACS as an example for Ground processing operations, the subcategories of the HFACS tool can be modified to reflect the specific tasks performed within that operation. For example, under the Level 2 *preconditions of unsafe supervision* subcategory of failure *to correct a known problem,* the subcategory example *failure to stop work due to a safety/hazard concern* (GPO causal factor stated earlier) could be added to the subcategory, due to this being a potential causal factor in KSC ground processing operations.

5.0 Conclusion

The case study in this report exhibits how the HFACS tool can be used to categorize human error causal factors in an investigation or retrospectively in order to incorporate mitigations from lessons learned for future operations. Although this case study primarily focused on an accident investigation, this tool can also be used to proactively conduct human factors risk assessments throughout the design process. The case study shows that the HFACS analysis tool can be used for ground processing operations; therefore, if it is not determined that it can meet the specific criteria (as stated in the NASA study 2006), then a modified version could be established and

followed. Using the process identified in the Discussion section, this tool can be modified to analyze other complex operations. Even though it is difficult to fully demonstrate in an article how this tool can be used, it can be seen how a similar process could be used to identify human casual factors.

6.0. Acknowledgments

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APPENDIX A

In 2006, research was done by the NASA Office of Safety and Mission Assurance (OSMA) with experienced HRA analysts to evaluate the current literature and source of HRAs that are prevalent today [3]. The NASA guidance discussed applicable HRAs for NASA applications and highlighted methods that can support Probabilistic Risk Assessments (PRAs) [3].

This paper will also provide a comparison between the advantages, disadvantages and applicability to complex space operations of the HRAs listed in the OSMA study as well as other prevalent HRAs.

1. Human Reliability Assessments (HRA)

Human Reliability Assessments (HRA) are designed to help reduce the likelihood of error [7]. HRAs deal with analyzing the human error potential within a system that typically happens within a quantitative risk assessment framework [7]. HRA approaches are typically grouped into two classifications; those using databases and others using expert opinion [7]. Human Error Identification (HEI) approaches are typically grouped into two categories as well: qualitative and quantitative. The qualitative approach is used to define the type of errors that occur within a specific system. The quantitative approach delivers a numerical probability that an error can occur within that system [18].

An important part of an HRA is the identification of Performance Shaping Factors or Contributing Factors to the human error incident. HRA Performance Shaping Factors (PSF) are defined as causes that can affect human performance [8].

Studies have shown that very few HRA methods provide step by step procedures or processes for following the HRA process [3]. To date there is no known process specifically and uniquely created for all aspects of NASA's Ground Processing Operations. The current body of knowledge concerning this effort is dependent upon using the current HRA methodologies that exist to perform and meet the HRA needs for these operations, thus causing human error analysts to use some combination of HRA methods [3].

Complex space operations, such as NASA KSC Ground Processing Operations are very unique and require a methodology that is specifically developed for identifying, evaluating, calculating the human error probability, and categorizing remedial measures to reduce human error incidents during ground processing operations.

A comparison table of the advantages and disadvantages of the HRAs that were selected by the NASA OSMA 2006 study for HRA Comparison, along with additional HRAs are provided in Table A.1. The HRAs were selected because they are considered current HRA tools used in High Hazard Human system interface design [24], and others for their potential applicability to complex systems, such as NASA Ground Processing Operations. The criteria for this study's selection is provided in Table A.2.

Table A.1: HRA Advantage and Disadvantage Comparison Table [1]

Human Error Identification Methods	Advantages	Disadvantages
Systematic Human Error Production and Prediction Approach (SHERPA)	Offers organized and complete approach to human error prediction, Easy to use method; Error classification is generic, thus allowing it to be used in various fields. Proven successful in a number of other domains [18].	Exhausting and time consuming for large complex tasks; Task Analysis adds addition time and does not consider system organization errors [18].
Human Error Template (HET)	HET method is easy to use and implement; error codes are generic and can be used for different fields; the classification helps cue the analyst for probable errors [18].	This tool can be tedious for complex large tasks; Tool does not address the cognitive aspect of errors, Tool only deals with the system or organization error and only focuses on the most difficult aspects of system operations [18].
Technique for the Retrospective and Predictive Analysis of Cognitive Errors (TRACEr)	Emerges as a complete method for error prediction and analysis [18].	Despite the appearance of a complete system, it also appears to be unnecessarily complicated. There are no verified confirmations of studies successfully using this method, For Complex tasks this tool can be tedious [18].
Task Analysis for Error Identification (TAFEI)	Organized and exhaustive procedure; Flexible basic approach [18].	Methodology is not a quick approach; Resource intensive, taking a long time to reach the end for even mild complex systems [18].
Human Error (HAZOP)	Methodology is usable in different fields; Known as an easy to learn and use tool; Guidewords can be used in different fields, due to its generic terms [18].	Application is time consuming. Methodology generates large data that has to be documented and assessed. Tool can be labor intensive [18].

Human Error Identification Methods	Advantages	Disadvantages
Technique for human Error Assessment (THEA)	THEA is an organized approach; a Generic tool that can be used in different fields; THEA's questions assist in the analyst identifying probable errors.	THEA can be resource intense and the analysis time consuming; There is limited validation evidence associated with THEA.
System for Predictive Error Analysis and Reduction (SPEAR)	Structured approach; Easy to learn, use and apply; Uses generic terms allowing it to be used in various fields [18].	Methodology time consuming for complex operations; Cognitive aspect of human error is not considered; Appears to be very similar to SHERPA
Human Error Assessment and Reduction Technique (HEART)	Useful for prediction and quantifying human error likelihood or failure within complex systems; Easy to use; Minimal training required [1].	HEART Methodology is subjective to SME assessment, thus affecting the consistency [1].
The Cognitive Reliability and Error Analysis Method (CREAM)	Considered an organized system approach to quantifiably identifying human error; Very detailed [1].	Time consuming to implement; May be considered complicated for a novice analyst; Appears complicated in application [1].
Human Factors Analysis and Classification System (HFACS)	Helps categorize and classify human error into four levels of failures [1].	Originally developed for Navy and Marine Corp. Will need to be modified for use in other fields [1].
Technique for Human Error Rate Prediction (THERP)	THERP can be used for task performance prediction while designing the Human System Integration (HSI) interaction. [24].	THERP does not offer clear processes for performing error identification [3].
Human Error Risk Management for Engineering Systems (HERMES)	The HERMES methodology has presented proficiency and usefulness in an actual and complex application [24].	The application of HERMES is restricted to the identification of safety critical factors, or Indicators of Safety (IoS), and their dissemination into RSA-Matrices that serve the resolution of outlining the existing level of safety within the organization

Human Error Identification Methods	Advantages	Disadvantages
		and describing the position methods for audits in the future [18].
Nuclear action reliability assessment (NARA)	Similar to HEART method; Provides more specific information for generic tasks [17].	NARA does not provide clear direction on task decomposition [3].
Standardized Plant Analysis Risk HRA Method (SPAR-H)	Projected to be a simple HRA method for estimated human error probabilities in plants.	SPAR-H does not specifically explain its HEPs terms "action" and "diagnosis" failures [3]. SPAR-H does not offer much direction for error identification.
Human Error Rate Assessment and Optimizing System (HEROS)	The importance of the Performance Shaping Factors (PSF) and Performance Influence Factor (PIF) values can be calculated for optimizing the man-machine system [15].	Even though is it minimized, there is still some level of subjectivity when vague linguistic statements on PSFs are selected and modified, then conveyed into expressions of fuzzy numbers or intervals to allow mathematical operations to be performed on them [15].

Multiple studies of the listed HRAs in the table above, show that these methods were not designed for ground processing operations. Many were designed for complex operations, such as the Nuclear Reprocessing Industry, Air Traffic Control, Chemical processing industry, and the Civil Aviation field, but not specifically for the Space Exploration. Due to NASA's unique operations, the HRAs and PSFs used in Space Operations would need to relate to ground processing operations, zero gravity, microgravity and isolation on crew performance to effectively deal with human error for Space Exploration [3, 1].

This review's focus is on NASA Ground Processing Operations, and the HRAs discussed above do not address the unique aspect of hardware that will be processed during Ground Operations and eventually placed into a zero-gravity environment.

In the NASA 2006 study, Ground processing operations is considered one of 6 categories in which NASA human activities relate to Space Flights. The remaining 5 categories consist of Space Flight Dynamic Phases, Intra Vehicular Activities (IVA), Extra Vehicular Activities (EVA), Destination and Surface Operations and Earth Landing [3].

2.0 NASA 2006 HRA Attributes and Selection

In the NASA 2006 study, the attributes selected for evaluation, used and compared for the HRA Method were provided. Below are two tables (Table A.2 and Table A.3) listing the attributes and HRA selections for review.

Table A.2: NASA Attributes used for HRA Method Comparison [3]

	NASA Attributes used for HRA Method Comparison
1	Development Context
2	Screening
3	Task Decomposition
4	PSF List and Causal Model
5	Coverage
6	HEP Calculation Procedure
7	Error-Specific HEPs
8	Task Dependencies and Recovery
9	HEP Uncertainty Bounds
10	Level of Knowledge Required
11	Validation
12	Reproducibility
13	Sensitivity
14	Experience Base
15	Resource Requirements
16	Cost and Availability
17	Suitability for NASA Applications

Table A.3: NASA HRA Selection [3]

NASA HRA Selection [3]
1. Technique for Human Error Rate Prediction
2. Accident Sequence Evaluation Program
3. Success Likelihood Index Methodology
4. Cognitive Reliability and Error Analysis Method
5. Human Error Assessment and Reduction Technique
6. Nuclear Action Reliability Assessment
7. A Technique for Human Event Analysis
8. Connectionism Assessment of Human Reliability
9. Standardized Plant Analysis Risk HRA Method
10. University of Maryland Hybrid
11. Commission Errors Search and Assessment
12. Human Factors Process Failure Modes & Effects Analysis
13. Time Reliability Correlation
14. EPRI Caused Based Decision Tree

The NASA OSMA study evaluated 14 HRA methods against 17 attributes for HRA comparison. The focus of their applicability was to concentrate on the various human interfaces for hardware preservation activities. The study's prime focus was to propose recommendations for the "quantitative analysis of space flight crew human performance in the support of Probabilistic Risk Assessments (PRA)" [3].

Because of the NASA 2006 assessment, 4 HRA methods were selected as an appropriate aerospace application when leading NASA PRAs. These methods are: The Technique for Human Error Rate Prediction (THERP), Cognitive Reliability and Error Analysis Method (CREAM), Nuclear Actions Reliability Assessment (NARA) and Standardized Plant Analysis Risk HRA Method (SPAR-H) [3]. Nonetheless, the study identified that these 4 methods did not meet all of the NASA selection criteria individually. These methods were also selected for completed Probabilistic Risk Assessments (PRAs) on new space flight vehicle system designs. They were

not selected for Ground Processing Operations, which include processing hardware, vehicle maintenance and processing [3].

According to the NASA 2006 study, CREAM was used in two NASA Probabilistic Risk Assessments (PRAs). One for a Space Shuttle Human Reliability Assessment (HRA) and another for the International Space Station HRA. At that time no results of the HRAs were publicly released. The current applicability of CREAM's human error probability in relation to NASA's specific tasks were still under review [3].

The NASA OSMA assessment determined that Ground processing activities better complemented the conditions for which THERP was established; however, this methodology did not address human performance in flight, zero gravity, or microgravity environments [3].

"The views and opinions expressed in this article represent the personal opinions of the author and do not reflect the opinions of the National Aeronautics and Space Administration or the Kennedy Space Center." Tiffaney Miller Alexander, PhD